Advancements and Integration: Exploring the Evolution of Automation in Radiotherapy Treatment Planning

Gary Bee

Purpose/Objective(s):

This presentation explores the historical progression and current state of automation in Radiotherapy (RT) treatment planning. We will examine the evolution of RT technology, the motivations behind seeking automations, potential challenges, and the possibilities for the future.

Materials/Methods:

Drawing from personal experience and industry insights, we will discuss the role of automation in RT planning. We will delve into the meaning of automation in the context of modern RT planning, including the emergence of Software-as-a-Service (SaaS) modular solutions and automation features within Treatment Planning Systems (TPS). Additionally, we will address the integration challenges faced by vendors and healthcare institutions including scalability, standardisation, and the importance of seamless integration in healthcare settings to enhance accuracy and efficiency.

Results:

Through historical analysis, we will showcase the progressive integration of computerised automations in RT. We will highlight how software vendors, including Linac manufacturers, are increasingly aware of the automation requirements in treatment planning. The collaboration between software development experts and healthcare professionals has paved the way for rapid advancements and large-scale innovation in the field. We will showcase specific TPS automations and a system of integrated components and software-enabled collaboration between clinical physics experts and software developers, enabling scale, rapid development, and the creation, testing and release of optimisation templates. This approach acts as a force for standardisation and establishes a direct connection to the clinician requirements.

Conclusion:

To achieve safe and rapid developments in RT planning automation, digital integration across all system components/services and a scaled approach to collaboration between clinicians and software development experts are crucial. This includes digitising and integrating constraints and objectives for each component of the treatment planning process. By leveraging the power of automation and seamless integration, we can enhance the accuracy, efficiency, and overall effectiveness of the treatment planning process.

Taking automated radiotherapy planning to the next level: automated batch planning via scripting

[1]Kirby J, [1]West N, [2]Wheeler P
[1]Northern Centre for Cancer Care, The Newcastle upon Tyne Hospitals NHS FT, UK.
[2]Velindre Cancer Centre, Velindre University NHS Trust, Wales.

Background.

The manual creation of radiotherapy treatment plans is a time-consuming process where variation in plan quality across a cohort of dose planning staff can be expected.[1] There are now a variety of techniques utilised for the automated planning of individual patients.[2] One such method devised by Wheeler et al[3] is 'EdgeVcc' which uses a protocol based automatic iterative optimisation algorithm that incorporates clinician preferences relating to the trade-offs of clinical objectives. The use of such an algorithm requires no human interaction during the optimisation phase of treatment planning. This opens the door for more efficient work practices where the optimisation of many patient plans can be batched together in the background. Here we discuss the design and implementation of a system that is able to continuously batch plan patients using the underlying EdgeVcc automated planning algorithm.

Methods.

Python scripts were created for use with the RayStation (v9B) treatment planning system (TPS). After the required OARs and PTVs have been created for the patient, a script is used to add the patient to a batch queue (stored in an SQLite database). A graphical user interface (GUI) is shown to the user to allow them to view the queue and to make simple interactions such as removing a patient from the queue or to change the order. In the background, on one of the TPS servers, a separate script runs continuously that creates a plan and optimises for any patients that are added to the queue. Within normal working hours a single license is used to plan patients but outside of working hours the batch planning script is allowed to plan patients simultaneously limited by the number of available licenses. Once planning is complete, the log file is available to view by planners and any errors are shown within the batch queue GUI.

Results & Discussion.

A batch planning process has been designed that is capable of automated planning using EdgeVcc and RayStation for any calibrated (via the EdgeVcc calibration process) treatment protocol. The system is currently calibrated for prostate and seminal vesicles with 60Gy/20# and it is expected to add additional protocols in the near future. Maximum capacity on a single server (with potential to expand to additional servers) with this protocol (~20 minutes per patient) is approximately 30 patients during working hours and ~200 patients outside of working hours. This leads to a change in the working practices of dose planners whereby they no longer need to be present during the optimisation and dose calculation phases of dose planning, giving them time to focus on other tasks. When combined with automated contouring, there is potential to streamline the planning process and minimise the time between planning scan and treatment. This batch planning concept would also work with other automated planning solutions and is a more efficient use of time whilst maximising plan quality across the patient cohort.

Conclusion.

We have demonstrated that the automated batch planning of patients is possible and has the potential to improve workflows, shorten care paths and reduce pressure on busy dose planning departments.

Key references.

[1] Nelms B, et al. Variation in external beam treatment plan quality: An inter-institutional study of planners and planning systems. Pract Radiat Oncol. 2012:2(4).
[2] Moore K. Automated radiotherapy treatment planning. Semin Radiat Oncol. 2019: 29(3).
[3] Wheeler P, et al. Utilisation of pareto navigation techniques to calibrate a fully automated radiotherapy treatment planning solution. Phys Imaging Radiat Oncol. 2019:10.

Creation of a Deep Learning treatment planning model based on CHHiP trial

Timothy Atkins, Simon Whittle, Rasmus Helander, Fredrik Löfman

Background. Machine Learning (ML) based treatment planning is a technique for automating the generation of deliverable treatment plans. This work investigates the process of developing and evaluating a deep learning (DL) based approach to plan generation following the hypofractionated arm of the CHHiP trial for prostate treatments [1].

Methods. 100 patient datasets were selected from patients previously treated at the RUH Bath. Each of these datasets were assessed to ensure that they delivered dose distributions that were acceptable according to the CHHiP trial criteria. These datasets were used to train (90 datasets) and validate (10) a UNet convolutional neural network (CNN) to predict a dose distribution based on 3D binary representations of the bladder, rectum and target volumes. The UNet dose distribution was then utilised in a dose mimicking/optimisation pipeline to generate deliverable plans. The settings for post-processing and dose mimicking were configured using feedback from comparison of the resultant plans with the clinical plans on an independent set of 10 cases. The dose distributions created by the final model were compared using a Wilcoxon signed-rank test.

Results. All dose constraints defined in the CHHiP trial for the bladder, rectum and PTVs were satisfied for all test patients. However, two issues were found with the spatial properties of the first iteration of the model upon slice-by-slice inspection of the dose distribution. These two issues were remedied in a second and third iteration of the configuration, see Figure 1. For the third version, statistically significant ($p < 0.05$) improvements compared to the clinical plan was observed for most of the dose constraints considered, see Table 1.

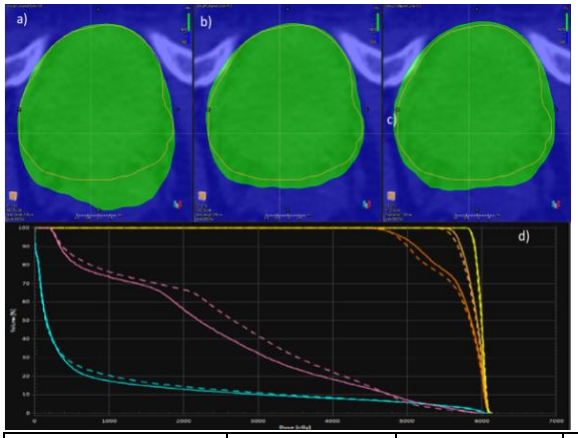


Figure 1 a)-c). Isodose cloud for 45.7Gy together with PTV_5760 (orange) for the first, second and third versions of the post-processing and dose mimicking settings respectively. a) the isodose area extends too far past the PTV posteriorly, which the anterior margin to the structure is too small. b) the posterior extension is solved but the anterior margin is still too small. c) the anterior margin is sufficient. d) DVHs for bladder (blue), rectum (pink), PTV_4800 (orange), PTV_5760 (beige) and PTV_6000 (yellow) for the clinical plan (dashed) and the ML plan (solid) generated by the third version of the settings.

Goal	CHHiP dose Constraint	CP	DLP	p
PTV_6000: D99%	>57.0	58.49 (0.12)	58.49 (0.07)	0.922
PTV_5760: D99%	>54.7	55.44 (0.31)	56.05 (0.10)	0.002
PTV_4800: D99%	>45.6	47.70 (0.40)	47.11 (0.40)	0.002
Rectum: D3%	<60.0	56.09 (1.96)	56.73 (1.94)	0.02
Rectum: D15%	<57.0	47.44 (4.10)	46.96 (5.01)	0.275
Rectum: D30%	<52.8	38.17 (5.52)	36.43 (6.40)	0.004
Rectum: D50%	<48.6	27.95 (4.71)	25.81 (5.77)	0.014
Rectum: D60%	<40.8	23.79 (3.46)	21.51 (4.65)	0.014
Bladder: D5%	<60.0	55.68 (3.07)	55.91 (3.62)	0.084
Bladder: D25%	<48.6	24.35 (8.91)	21.34 (5.97)	0.002
Bladder: D50%	<45.6	11.23 (7.20)	8.80 (5.97)	0.004

Table 1 Dosimetric evaluation of mean doses across 10 DL-generated plans (DLP) as compared to clinical plan (CP). DLP were generated with the third version of postprocessing and dose mimicking settings. Green cells indicate statistically significant differences in favour of the DLP. Red cells indicate statistically significant differences in favour of the CP. Dose constraints are from the CHHiP trial for the ROIs relevant to the study. Dose values are in Gy. Values in brackets indicate 1 standard deviation.

Discussion. This work has outlined the process of developing and testing a DL model intended for implementation in the clinical workflow. In terms of OAR sparing the model outperforms the benchmark data while achieving clinically acceptable target coverage. The development of the model stresses the importance of configuring settings for a specific clinical use case, while highlighting that retraining of a neural network is not mandatory to improve results. The first patient planned using this model was treated at the RUH in January 2023.

Conclusion. A clinically acceptable DL based planning technique for prostate was developed and tested during a collaboration between RaySearch Laboratories and Royal United Hospitals, Bath.

Key references. [1] Dearnaley et al. https://doi.org/10.1016/S1470-2045(16)30102-4

Knowledge-based planning site by site implementation process

Miranda Frizzelle

Background.

With the introduction of 17-day pathways for multiple new sites in radiotherapy [1], knowledge-based planning has become increasingly important in helping to reduce the planning workload for departments [2-5]. A standardised approach to allocating appropriate sites, testing and clinically trialling models has been implemented with strategies in place to feedback and adjust models to achieve optimum results.

Methods.

The implementation process involves an initial patient audit stage, creating generalised Rapidplan models which apply to a wider range of prescriptions, and a testing phase with structured dose objective reporting allowing clear comparisons between techniques. The method was fine-tuned and optimised during a project to validate a Rapidplan 'super-model', created by combining data libraries from three centres within the UK Rapidplan Consortium [2]. This utilised the expertise and knowledge of multiple centres to maximise the robustness and clinical success of the final model.

Discussion and Results.

Rapidplan has been in use at UCLH since 2019 following the successful implementation of a lower head and neck model which reduced planning and optimisation times from ~2.5 hours to ~15 minutes. Since then, four more site models have been commissioned for use, and a further three are in progress. Overall, the process has streamlined the introduction of new models, allowing faster relief of the planning workload and increased automation within the planning pathway.

Conclusion.

We propose a clear process which enhances the applicability of knowledge-based models, improves the efficiency of implementation and allows easy collaboration between colleagues to share the workload in creating models whilst ensuring safe operation. The aim is to share the step-by-step process with the aim of improving knowledge-based planning model implementation nationally.

Key references.

[1] Adult External Beam Radiotherapy Services Delivered as Part of a Radiotherapy Network, NHS England, Service Specification 170091S, 2019.
[2] Frizzelle M, Pediaditaki A, Thomas C et al., Using multi-centre data to train and validate a knowledge-based model for planning radiotherapy of the head and neck. Phys Imaging Radiat Oncol. 2022 Jan 25;21:18-23.
[3] Tol J.P., Delaney A.R., Dahele M., Slotman B.J., Verbakel W. Evaluation of a Knowledge-Based Planning Solution for Head and Neck Cancer. Int J Radiat Oncol Biol Phys. 2015;1:612–620.
[4] Nwankwo O., Mekdash H., Sihono D.S.K., et al. Knowledge-based radiation therapy (KBRT) treatment planning versus planning by experts: validation of a KBRT algorithm for prostate cancer treatment planning. Radiat Oncol. 2015;10:111.
[5] Ma C., Huang F. Assessment of a knowledge-based RapidPlan model for patients with postoperative cervical cancer. Precision Radiat Oncol. 2017;1:102–207.

An assessment of the accuracy of the organ at risk contours for five commercial AI contouring solutions

P. Doolan[1*], S. Charalambous[1], Y Roussakis[1], A Leczyski[1], K Ferentinos[1,2], I Strouthos[1], C Zamboglou[1], E Karagiannis[1,2]
(1) German Oncology Center, (2) European University Cyprus
*Corresponding author: paul.doolan@goc.com.cy

Background. Auto-segmentation with artificial intelligence (AI) can remove inter- and intra-observer variability in contouring, improve the quality of contours and also reduce the time taken to conduct this manual task. In this work we assess the AI auto-segmentation contours produced by five commercial vendors against a common dataset..

Methods. Organ at risk (OAR) contours generated by five commercial AI auto-segmentation solutions (Mirada (Mir), MVision (MV), Radformation (Rad), RayStation (Ray) and TheraPanacea (Ther)) were compared to expert contours from 20 breast, 20 head and neck, 20 lung and 20 prostate patients. The expert contours were drawn by a Radiation Oncologist following RTOG atlas, Brouwer *et al* (1), Scoccianti (2) or Gay (3) guidelines. Comparisons were made using geometric similarity metrics including volumetric and surface Dice similarity coefficient (vDSC and sDSC), Hausdorff distance (HD) and Added Path Length (APL). The time taken to manually draw the expert contours and the time to correct the AI contours were recorded.

Results. Each AI auto-segmentation solution offered different numbers of contours at the time of the study (Mir 99; MV 142; Rad 83; Ray 67; Ther 86). Averaged across all structures, the median vDSCs were good for all systems: Mir 0.80; MV 0.85; Rad 0.83; Ray 0.85; Ther 0.87 (see example for prostate in Fig. 1). All systems offer substantial time savings, ranging between: Breast 14.2-20.6 mins; head and neck 80.7-104.6 mins; lung 20.0-25.6 mins; prostate 33.9-41.1 mins. The time saved, averaged across all sites, was similar for all systems: Mir 42.2 mins; MV 46.0 mins; Rad 38.0 min; Ray 46.0 mins; Ther 47.8 mins.

Conclusion. All five commercial AI auto-segmentation solutions evaluated in this work produce high quality, consistent, contours while simultaneously offering significant time-saving. Compared to manual contouring they could be used to make the radiotherapy workflow more efficient and standardized.

Key words. 1. Artificial intelligence, 2. Contouring, 3 Geometric similarity.

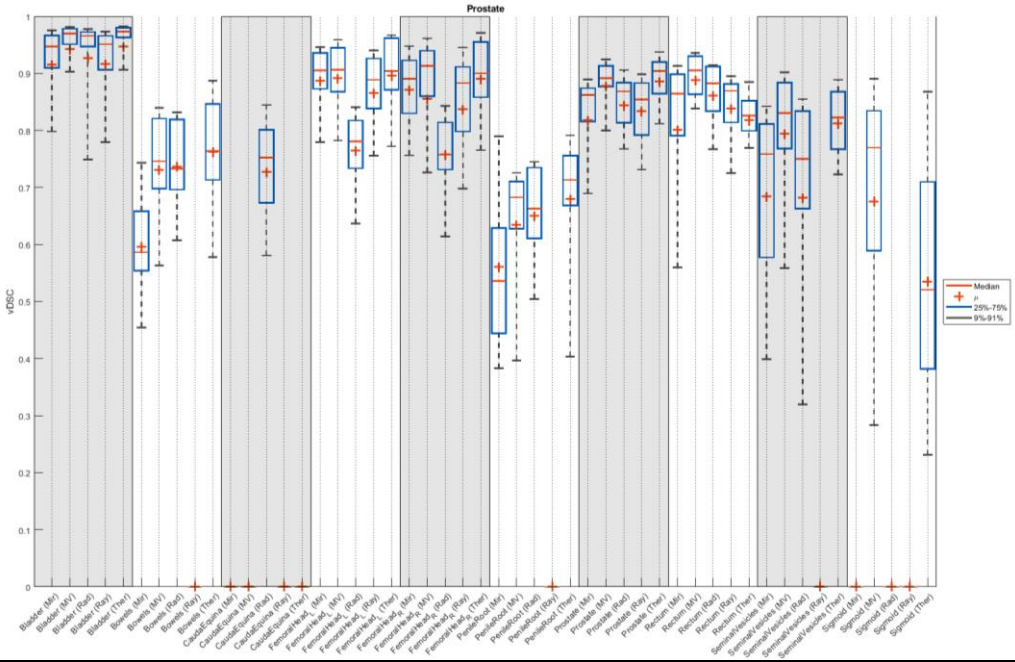


Figure 1: Volumetric dice similarity (vDSC) coefficients for twenty prostate cases, compared to expert manually-drawn contours, for each commercial AI contouring solution. Mir = Mirada; MVis = MVision; Rad = Radformation; Ray = RayStation; Ther = Therapanacea.

Title of Study: Evaluating the Safety and Utility of Auto-Segmentation Software using ProKnow

Submitters details: Alexandra Constantinou (CUH), Andrew Hoole (CUH), Raj Jena, Andrew Robinson, Liam Stubbington

Background. Automation in Radiotherapy is desirable but it is imperative that it is rigorously evaluated and implemented safely.[1] CUH are currently developing an in-house auto-segmentation software for organ at risk (OAR) contouring in radiotherapy treatment planning, OSAIRIS, with funding from an NHSx AI Award. Part of the development of a medical device involves carrying out a clinical evaluation to demonstrate its benefits, compare its performance to other devices, and evaluate its safety. To this end, our first aim was to set up a 'Turing test' to determine the clinicians' subjective assessments of the contour quality of OSAIRIS compared to clinician gold-standard contours and those from two other auto-segmentation software.[2] Here, we would obscure the origin of a structure-set, and ask clinicians to review them and rate each contour's clinical acceptability. The second aim was to set up a 'mystery shopping' exercise, in which we would introduce discrepancies into the OSAIRIS output contours, and ask clinicians to edit them until they are clinically acceptable, to see if they are able to pick up any serious errors, were any to be made by OSAIRIS.[3] For this exercise, it was imperative that we use a platform that is not used for treatment planning, so we could separate this pilot study from the clinical workflow. We therefore decided to use ProKnow to host both of these evaluations.[4]

Methods. To set-up the evaluations, we made use of ProKnow's various features such as its API functionality, collections and custom metrics, which we used to record the clinicians' contour acceptability ratings. We generated scripts to automate as much of this process as possible.

Firstly, for the utility evaluations, there was one gold standard clinician structure set, and 3 auto-segmentation structure sets per patient scan for clinicians to review. Using ProKnow's API, we wrote scripts to create a separate collection for each clinician, with separate patients with a consistent naming system, and upload the scans and structure sets in batch. Custom metrics were created in ProKnow for each OAR so that clinicians could rate them and these were ascribed to each structure set using the API. We wrote scripts to ensure the naming and colour conventions used for the structure sets were consistent, so that clinicians would not know their origin. These custom metrics were then exported using another script and were subsequently analysed.

Secondly, for the 'mystery shopping' exercise, we had one OSAIRIS-generated structure set for each of the five patient scans used, and we had introduced discrepancies into them. In a similar fashion to the previous evaluation, collections and patients were created for each clinician using a script, and the scans and structure sets were subsequently uploaded using another script. The edited contours were then exported using a script.

Results. We were able to set up the two evaluations as described. We have had good clinician engagement so far, with three clinicians completing both evaluations for the Prostate, and two for the Head and Neck.

Discussion. This result is significant, as it paves the way for ProKnow to be used in future evaluations of automation techniques and new technologies. ProKnow is currently available to all NHS Radiotherapy departments, and enables safe data sharing between them, with built-in anonymisation. This opens the door to larger-scale evaluations involving multiple trusts.

Conclusion. We have shown that it is possible to use ProKnow to set up an evaluation for auto-segmentation software with good clinician engagement. This paves the way for future large-scale evaluations of automation devices in radiotherapy.

Key references. [1] Kelly, C.J., Karthikesalingam et al. (2019) 'Key challenges for delivering clinical impact with artificial intelligence', *BMC Med,* vol. 17, article 195. [2] Turing, A.M. (1950). 'Computing Machinery and Intelligence', *Mind*, vol. 59, no. 236, pp. 433–460. [3] Goddard, K. et al. (2012) 'Automation bias: a systematic review of frequency, effect mediators, and mitigators'. J Am Med Inform Assoc, vol 9, no. 1, pp. 121-7. [4] Elekta, ProKnow. Available at: https://proknow.com/.(Accessed 23/03/23).

The evolution of the clinical treatment planning system scripting service over 7 years at the NCCC

[1]Kirby J, [1]Dixon B
[1]Northern Centre for Cancer Care, The Newcastle upon Tyne Hospitals NHS FT, UK.

Many commercial radiotherapy treatment planning systems (TPS) include scripting functionality allowing users to optimise the planning workflow and enabling interactions beyond the use of the standard interface. This functionality can lead to improved efficiency as time-consuming repetitive steps are completed without requiring user interaction, allowing staff to spend their time where they add more value. Safety is improved with reduced likelihood of transcription errors, greater consistency in approach and a reduction in small errors that are inevitable when a human completes a repetitive task[1]. Scripting also makes it easier to work with the vast quantity of data available in the TPS and other clinical systems, maximising process efficiency and unlocking the potential for data mining and analysis[2].

Since commissioning the RayStation (RaySearch Laboratories)TPS in 2016 at the NCCC, the clinical scripting service within radiotherapy physics has evolved from one or two users using the built-in script recording functionality for very simple tasks to having a team of scientists developing a range of more complex scripts that share a suite of in-house developed modules. Currently, there are 31 clinical scripts in use or in development covering areas such as ROI creation, automated planning, secondary dose calculation for an independent TPS, plan checking, CBCT dose evaluation and quality assurance processes. Scripting therefore plays a large role at all stages within the planning process and complements other automation tools such as AI contour segmentation to optimise the pathway.

The management of the scripting service has necessarily developed over this time as the quantity and complexity of the scripts have grown. A new software lifecycle has been introduced with version control and each stage of the software lifecycle tracked using Git (open source) and Azure DevOps (Microsoft Corporation), providing an audit trail. The quantity and quality of documentation has increased to be compliant with current and future legislation (as described in IPEM guidance[3]), with additional workload minimised by the use of an automated document creator and management within the quality management system, Q-Pulse (Ideagen Products Ltd.).

Current process developments include the logging of script uses and code exceptions in an SQLite database to demonstrate the value of specific scripts, enhance identification of bugs and facilitate future audit.

From small beginnings, the scripting group and associated processes have necessarily expanded to keep up with demand and to aim for best practice. The value of the group has been recognised by the department with investment in external training and the creation of a new lead clinical scientist role for clinical and scientific computing in radiotherapy. It is expected that the team will continue to evolve for the benefit of both patients and staff as new technologies, techniques and workflows are developed.

Key references.

[1] Jensen N, et al. Impact of automation in external beam radiation therapy treatment plan quality control on error rates and productivity. Radiation Oncology Biology Physics, Oral Scientific Session. 2018:102(3).
[2] Mayo C, et al. The big data effort in radiation oncology: Data mining or data farming? Adv Radiat Onclogy.2016:1(4).
[3] IPEM. Best-practice guidance for the in-house manufacture of medical devices and non-medical devices, including software in both cases, for use within the same health institution. Version 2.1.

Scripting with Varian's ESAPI: The Beginner's Experience

Glenn Whitten, Denise Irvine
Radiotherapy Physics, Northern Ireland Cancer Centre, Belfast.

Background.

Many processes within the radiotherapy and treatment planning workflow involve repetitive and time consuming tasks[1]. With complexity of planning techniques and pressures on the workforce increasing, being able to harness the power of automation and scripting can prove to be a valuable tool in improving efficiency, safety and quality[2, 3]. Often the idea of scripting can be daunting however with some basic training and understanding of the resources available scripts can be created and put to use in both a safe and efficient way which will bring benefits to your department.

Methods.

Varian's Eclipse scripting application programming interface (ESAPI) became available in v11 and we have been using it since 2019 in v15.6 and v16.1. ESAPI allows the user to create scripts that leverage the functionality of Eclipse and can retrieve plan, image, dose, structure and DVH information. With automation it is possible to create and modify structure and plan data and execute dose calculation and optimization algorithms. A learning experience was developed to gain familiarity with ESAPI which included acquiring the correct tools to script, using online resources and attending the Varian ESAPI Basics course. Within the NICC treatment planning department, areas where scripting could be of benefit to improve the workflow were identified and scripts were created and put in to use. This presentation aims to give an overview of what is being used at the NICC showing our scripting journey from novice to clinically useful scripts developed by a non-expert.

Results.

Within the treatment planning database there is a wealth of information about treatment plans. This information can be harnessed through data mining of DVHs for a cohort of patients to inform service development and local quality improvement. Plan checking is a task which requires the user to click through multiple windows within the treatment planning system retrieving often the same information for every patient. A script was developed to assist in the checking of plans which automatically populates a checklist that the checker is required to retrieve and evaluate, reducing the amount of 'clicks' and time required to view the information. A script was also created to compare the plan parameters set by a Clinician at VSim to the final plan issued for treatment to identify if any inadvertent changes have been made. Shift directions and magnitude from tattoos to isocentre for multiple coordinate systems can easily be scripted to give the correct information, removing the operator error and ensuring the instructions are correct each time. Site specific automatic plan generation scripts have been created to assist planners in performing repetitive tasks such as the generation of planning structures, placing beams, adding optimisation parameters, optimising and calculating plans enabling a VMAT plan to be generated with only one click in a few minutes.

Discussion.

Scripting with ESAPI reduces the time taken to perform repetitive tasks allowing staff more time to focus on the complex cases or devote further time to specific details. Scripting can reduce the chance of human errors and allows staff to harness the vast wealth of information stored within the Varian database. There are hurdles to overcome and it is important to operate within a quality framework but there are still many areas to further develop.

Conclusion.

ESAPI is a powerful tool which can be used by Varian users. This can be utilised by a computer programming beginner with a good understanding of Eclipse to create useful and valuable scripts which will help the department save time and reduce errors.

Key references.

1. Wang C, Zhu X, Hong JC, Zheng D. Artificial Intelligence in Radiotherapy Treatment Planning: Present and Future. Technol Cancer Res Treat. Vol 18, 2019.
2. Xhaferllari I, Wong E, Bzdusek K, Lock M, Chen J. Automated IMRT planning with regional optimization using planning scripts. J Appl Clin Med Phys. Vol 14, 2013.
3. Moore KL, Automated Radiotherapy Treatment Planning, Sem. in Rad. Onc. Vol 29, 2019.

Automation within the Prostate Brachytherapy Workflow

George Kirby, Gerry Lowe, Victoria Newton – Mount Vernon Cancer Centre

Background: Throughout the prostate brachytherapy workflow, time is an important constraint because of the potential movement of internally placed catheters as peri-prostatic oedema forms, causing caudal displacement, and leading to a geographic miss if uncorrected. 'Corrective Action' CT images are often obtained after the physics planning is completed to make these adjustments. Utilising automation techniques and automatic optimisation has the potential to reduce the time spent planning treatments, while producing clinically ready plans, thereby reducing the magnitude of oedema during the planning process.

Method: Following from the clinician contouring the OARs (Urethra and Rectum) and CTV, an Eclipse Scripting API (ESAPI) script has been written generate a set of optimisation structures for prostate planning: a contracted, inner urethra structure; an extended PTV structure; and a ring structure around the prostate. Legal dwell positions for the optimiser are set to be within the extended PTV structure, which allows the use of needles that are close to but not intersecting the PTV itself.

The Varian VEGO TG-43 optimiser is weighted heavily to reduce urethral dose, with the Inner Urethra structure being highly restrictive. There is also heavy weighting on maximum rectal dose, with a lower weighting on ring structure dose. This optimiser, new to us in the current Eclipse version, is a significant improvement over previously available optimisers.

Following the planning process, an ESAPI checking script is run to check for technical problems within the plan. This script will check: dwell times are within the correct range; plan data are correct, including course name, plan name and prescribed dose; needle lengths are standard and matching; reference points are placed and named. The plan is then ready to be checked and reviewed by the clinician and by a second, independent, physicist as usual.

Results/Discussion: For most whole-prostate treatments, a clinical plan that was within OAR thresholds was created quickly and automatically. In a retrospective sample of 8 patients, in every case a higher PTV coverage was achieved, and in 7 out of 8 cases the OARs remained below tolerance. Plans that were not clinically ready (such as the one case from the sample) were found to require minimal adjustment from a planner. The physics optimisation time was reduced from an average of 37 minutes (retrospective sample of 81 patients) to an average of 7.5 minutes (most recent 4 patients in series). For focal salvage cases, the results of optimisation heavily depended on the needle placement; these cases required manual planning.

By using the developed techniques, time can be saved in the planning phase, which would potentially remove the need for a 'corrective action' CT scan. The additional time could also allow for more efficiency within a department in the context of a large patient load. The checking script allows efficient detection of issues.

Conclusion: The results show that implementation of automation and scripting in HDR prostate planning has led to a large decrease in physics planning time. The plans produced have a good distribution, OAR doses within tolerance and a high coverage to the PTV. The results are based on whole prostate treatments and do not include focal treatments.

Key Words: *Brachytherapy, Automation, HDR, Prostate, Scripting, Optimisation*

References: *[1] T. Simnor et al, "Justification for inter-fraction correction of catheter movement in fractionated high dose-rate brachytherapy treatment of prostate cancer," Radiotherapy and Oncology 93, pp. 253-258, 2009.*

Development, evaluation and widespread implementation of Pareto navigation guided automated planning in the clinic

Wheeler P.A.[1], Berenato S.[1], Millin A.E.[1]

[1]Velindre Cancer Centre, Radiotherapy Physics Department, Cardiff, Wales, United Kingdom.

Background.

Current automated planning solutions are calibrated using trial and error or machine learning on historical datasets. Neither method allows for the intuitive exploration of differing trade-off options during calibration, which may aid in ensuring alignment with clinical preference. Pareto navigation provides this functionality and offers a calibration alternative. This work presents our experience in developing, evaluating and clinically implementing a fully automated radiotherapy planning solution which incorporates a novel multi-dimensional Pareto navigation calibration interface.

Methods.

The implemented 'Pareto Guided Automated Planning' (PGAP) methodology was developed in RayStation using scripting and consisted of a Pareto navigation calibration interface built upon a 'Protocol Based Automatic Iterative Optimisation' planning framework. Robust single institution evaluations against manually generated plans (MP) were performed for prostate (PSV, n=20), prostate and pelvic nodes (PPN, n=20), Extreme hypo-fractionated prostate (EHRT, n=22), head and neck (HnN, n=35) and two-phase PET adapted HnN (HnN_{PET}, n=9). In addition, a two centre multi-institutional study was performed for PSV ($PSV_{External}$, n=40). Validation for all sites included quantitative comparison across clinical dose metrics and blind qualitative review by a clinical oncologist. For PSV and PPN timing data was collected to estimate efficiency savings. Based on validation results and additional small scale implementation studies, fully automated PGAP was clinically implemented for PSV, EHRT, HnN_{PET}, anus, oesophagus, rectum and lung treatments, which represent ~ 30% of all radical indications. HnN implementation is due in the coming months. Our methodology has been adopted by an external institution, with implementation due Q3 2023.

Results.

Upon blind review 95%, 100%, 91%, 80%,100%, and 93% automated plans were considered clinically equivalent or superior to MP for PSV, PPN, EHRT, HnN, HnN_{PET} and $PSV_{External}$ respectively, with 92/134 AP plans considered clinically superior. For PSV and PPN hands on planning time was reduced by 94% and 79% respectively. A summary of the quantitative DVH comparison for key metrics is presented in Table 1. In general, automation led to statistically significant ($p<0.05$) reductions in mean dose for high priority OARs (e.g. rectum and parotid), but increases for low priority OARs (e.g. bladder). PTV coverage and conformality were nominally equivalent. Results for all small-scale implementation studies were also supportive of AP, leading to clinical rollout.

Table 1: Summary of validation studies, bold represents $p<0.05$.

Site	ROI	Metric	$VMAT_{Auto}$	$VMAT_{Manual}$
PSV (n=20)	PTV60	D98% (Gy)	57.90 ± 0.10	57.80 ± 0.20
		D2% (Gy)	**61.60 ± 0.10**	**61.70 ± 0.20**
		CI	**0.86 ± 0.01**	**0.84 ± 0.03**
	Rectum	Dmean (Gy)	**22.70 ± 3.90**	**25.10 ± 3.50**
	Bladder	Dmean (Gy)	**23.00 ± 9.10**	**22.20 ± 8.60**
	Bowel	Dmean (Gy)	8.60 ± 4.70	8.40 ± 4.70
PPN (n=20)	PTV60	D98% (Gy)	**57.80 ± 0.10**	**58.00 ± 0.10**
		D2% (Gy)	**61.70 ± 0.10**	**61.90 ± 0.20**
		CI	**0.82 ± 0.02**	**0.81 ± 0.03**
	Rectum	Dmean (Gy)	**29.50 ± 2.70**	**30.40 ± 2.60**
	Bladder	Dmean (Gy)	**33.00 ± 3.90**	**31.30 ± 3.50**
	Bowel	Dmean (Gy)	**18.70 ± 2.60**	**19.60 ± 2.60**
EHRT (n=22)	PTV36.25	D98% (Gy)	**35.40 ± 0.60**	**35.60 ± 0.70**
		D2% (Gy)	42.50 ± 0.20	42.50 ± 0.10
		Dmax (Gy)	43.00 ± 0.10	43.00 ± 0.20
	Rectum	V18.1Gy (%)	**16.90 ± 5.50**	**20.10 ± 5.90**
	Bladder	V18.1Gy (%)	18.60 ± 6.00	18.40 ± 6.20
	Bowel	V18.1Gy (cc)	**0.70 ± 1.50**	**0.30 ± 0.70**
HnN (n=35)	PTV66	D98% (Gy)	**63.50 ± 0.10**	**62.60 ± 1.10**
		D2% (Gy)	68.50 ± 0.10	68.50 ± 0.30
		CI	**0.80 ± 0.04**	**0.78 ± 0.06**
	Parotid_CL	Dmean (Gy)	**21.50 ± 7.10**	**24.70 ± 8.30**
	SpinalCord_5mm	Dmean (Gy)	**44.30 ± 3.20**	**46.90 ± 1.50**
	BrainStem_5mm	Dmean (Gy)	**41.00 ± 7.00**	**43.90 ± 7.00**

Discussion.

PGAP consistently yielded high quality plans that prioritised high priority over low priority objectives. Results of the blind reviews suggest this prioritisation was more congruent with clinical preference than MP and supported the use of Pareto Navigation as a calibration tool. In terms of clinical implementation, software development under a quality management system and calibration of automated solutions was time consuming, but once released for clinical use implementation was highly successful.

Conclusion. PGAP is a highly effective automated planning methodology, which is suitable for broad scope implementation and yields marked improvements plan quality and efficiency.

"A geometric analysis of Brainlab auto-contouring software for proton treatment planning of brain tumours"

Virginia Marin Anaya[1]; Alexander Grimwood[1]; Jaymisha Davda[1]; Caroline Thould[1]; Emma Dwyer[1]; Colin Baker[1]

(1) University College London Hospitals NHS Foundation Trust

Background:

Contouring of relevant structures in the vicinity of the tumour is currently performed manually. This is time-consuming, subjective and can delay the start of treatment. For brain patients, this can lead to poorer clinical outcome. Moreover, proton therapy is very sensitive to anatomical changes and re-planning, including re-outlining of structures, may be necessary. The aim of this study was to assess the feasibility of auto-contouring for proton treatment planning of brain tumours using Brainlab Elements version 1.6.1.38.

Methods:

Ten brain patients were selected retrospectively. The anonymised CT and MRI datasets were imported into Brainlab. For each patient, CT and MRI image fusion and distortion correction were performed. For brain, lenses, optic nerves, globes, cochleas and pituitary, CT was used for the generation of Brainlab auto-contours. MRI was selected for brainstem, chiasm, hippocampi, hypothalamus and cerebellum. Geometric analysis of the Brainlab contours was performed using several evaluation metrics such as the Dice Similarity Coefficient (DSC), the Mean Distance to Conformity (MDC) and the Target Registration Error (TRE). The manual contours on the planning CT by the oncologist were used as reference.

Results and discussion:

Table 1. Geometric analysis. Results expressed as median and range between brackets.

Structure	DSC	MDC (mm)	TRE (mm)	Volume Difference (%)	Sensitivity Index	Inclusiveness Index
Brain	0.97 (0.97, 0.98)	4.42 (3.55, 4.94)	1.01 (0.04, 4.02)	-4.18 (-4.57, -2.55)	0.95 (0.95, 0.97)	0.99 (0.99, 1.00)
Brainstem	0.89 (0.84, 0.90)	4.37 (3.10, 5.46)	1.19 (0.30, 3.34)	-0.38 (-8.82, 16.32)	0.88 (0.85, 0.91)	0.89 (0.78, 0.93)
Cerebellum	0.92 (0.91, 0.95)	3.48 (3.01, 3.80)	0.95 (0.43, 2.04)	-0.65 (-5.38, 2.46)	0.92 (0.90, 0.94)	0.93 (0.91, 0.95)
Chiasm	0.50 (0.22, 0.65)	4.10 (3.04, 8.69)	3.35 (2.00, 7.88)	-6.70 (-35.96, 68.42)	0.50 (0.19, 0.66)	0.51 (0.26, 0.75)
Cochlea Left	0.38 (0.20, 0.70)	3.37 (2.41, 4.06)	1.99 (0.61, 3.50)	26.79 (-33.33, 300.00)	0.48 (0.25, 0.67)	0.33 (0.13, 0.88)
Cochlea Right	0.52 (0.25, 0.78)	2.74 (1.95, 3.98)	1.24 (0.06, 4.17)	45.00 (-33.33, 350.00)	0.64 (0.43, 1.00)	0.44 (0.18, 0.88)
Globe Left	0.93 (0.83, 0.95)	2.36 (2.17, 3.06)	0.77 (0.07, 1.42)	-11.17 (-27.71, 23.54)	0.88 (0.72, 0.99)	0.98 (0.80, 1.00)
Globe Right	0.92 (0.87, 0.95)	2.43 (2.24, 2.87)	0.87 (0.28, 1.41)	-5.57 (-20.82, 6.64)	0.89 (0.78, 0.95)	0.96 (0.88, 0.99)
Hippocampus Left	0.65 (0.54, 0.73)	4.19 (3.38, 6.36)	2.29 (1.43, 6.81)	43.09 (5.07, 75.00)	0.80 (0.64, 0.89)	0.54 (0.46, 0.67)
Hippocampus Right	0.66 (0.51, 0.73)	3.92 (3.20, 6.44)	2.02 (0.77, 6.79)	34.50 (11.60, 73.95)	0.75 (0.65, 0.90)	0.59 (0.42, 0.65)
Hypothalamus	0.53 (0.11, 0.65)	3.82 (2.96, 5.10)	2.90 (1.35, 4.34)	53.80 (12.75, 1685.71)	0.70 (0.62, 1.00)	0.43 (0.06, 0.60)
Lens Left	0.74 (0.54, 0.83)	2.30 (1.39, 3.24)	1.09 (0.59, 2.35)	51.88 (27.78, 110.00)	0.92 (0.77, 1.00)	0.62 (0.41, 0.74)
Lens Right	0.73 (0.43, 0.85)	2.25 (1.01, 3.10)	1.04 (0.14, 2.08)	48.08 (13.33, 120.00)	1.00 (0.50, 1.00)	0.60 (0.38, 0.74)
Optic Nerve Left	0.61 (0.22, 0.68)	3.38 (2.73, 5.96)	2.07 (0.92, 9.23)	-42.07 (-59.70, -28.26)	0.46 (0.16, 0.58)	0.82 (0.36, 0.97)
Optic Nerve Right	0.54 (0.40, 0.65)	3.22 (2.57, 5.85)	2.84 (0.37, 5.35)	-57.52 (-66.67, -40.74)	0.38 (0.28, 0.51)	0.90 (0.70, 0.95)
Pituitary	0.40 (0.18, 0.46)	4.18 (3.86, 5.19)	2.75 (2.03, 3.44)	41.03 (-51.85, 900)	0.52 (0.30, 1.00)	0.37 (0.10, 0.62)

For brain, brainstem, cerebellum and globes, median DSC values were ≥0.89 and range DSC values were between 0.83 and 0.98. For all Brainlab contours, median MDC and TRE values were ~ 2-4mm and ~1-3mm, respectively.

Qualitative analysis of auto-contours by oncologists showed a preference towards editing auto-contours, if necessary, rather than outlining from scratch, saving overall contouring time.

Conclusion:

Brainlab is a promising tool for proton treatment planning of brain tumours. Its implementation could potentially improve contouring consistency; optimise clinical workflow, increasing patient throughput, whilst enabling effective use of staff resources and improving patients' outcome.

Feasibility of a simple KBP planning tool for head and neck radiotherapy planning.

Matthew Jones[1], Julia Handley[2], Gareth Baugh[1].

[1] Arden Cancer Centre, University Hospitals Coventry and Warwickshire, Coventry.
[2] The Christie NHS Foundation Trust, Manchester.

Background. Investigate the potential application, utilisation and clinical implementation of a simple knowledge-based planning solution for head and neck radiotherapy within a clinical radiotherapy department.

Methods. A knowledge base of 141 previously treated head and neck patients was created by extracting data using a Python data mining script and the existing scripting capabilities of the RayStation treatment planning system. This knowledge base was used to create three separate knowledge-based models to predict the optimal and mandatory achievable doses for the spinal cord, brainstem, and parotids respectively. The models were validated using a range of methods. A graphical user interface was developed and validated to display the predicted model doses from within the planning system.

Results and Discussion. It was demonstrated that the three models developed could accurately identify treatment plans in which the doses to the brainstem, spinal cord and parotids could be reduced without adversely affecting any other aspects of treatment plan quality. For a separate cohort of validation head and neck patients, it was shown that implementing the models could potentially reduce the maximum spinal cord, maximum brainstem and mean parotid doses by 5.42Gy, 3.62Gy and 5.93Gy respectively without adversely affecting plan complexity and surrounding organ at risk doses. It was also demonstrated that the developed GUI was accurate and could feasibly be introduced into routine clinical use.

Conclusion. Three simple knowledge-based models have been developed and validated which could be clinically implemented and potentially significantly reduce organ at risk doses for head and neck patients within the clinical radiotherapy department. These models present a low cost, accessible, and simple alternative to commercially available knowledge-based planning solutions.

Automating 4D Manual Delineation Treatment Pathways

M Tyyger [1] , A Clark [1], DW Smith [1], C Lai [1], M Nix [1], P Dickinson [1], B Al-Qaisieh [1], I Bond [1]

1. Leeds Cancer Centre, Leeds Teaching Hospitals NHS Trust, Leeds, UK

Background

The focus of automation in treatment planning is typically on radiotherapy planning or auto-contouring. However, the assistance of a script for even simple tasks can provide large benefits in treatment pathways. This is particularly true where many similar and repetitive actions are required, as this type of activity is prone to human error.

A local example is the workflow required for delineation of tumour volumes on 4D datasets for lung SABR treatments. The treatment planning system (TPS) did not provide suitable tools for a pathway without many repetitive actions, such as creating regions of interest (ROI) and copying their geometries between examinations. To perform this manually was deemed clinically unsuitable due to the high likelihood of errors, the training burden on oncologists, and the length of time required.

The aim was to produce a Python script which ran inside the TPS Python environment which could automate the non-delineation steps while guiding the user through the treatment pathway. Therefore, making the process more efficient and reducing the probability of errors.

Methods

Local Radiotherapy Physics and Clinical Scientific Computing teams collaborated to define a clinically robust treatment pathway and develop the necessary Python script. A Consultant Clinical Oncologist evaluated the suitability of the pathway and script.

To assess potential time saving impacts, two experienced RayStation users, a senior Dosimetrist and Medical Physicist, were timed performing the functional steps of the workflow both manually and using the script.

Results

A pathway (figure 1) and script were produced, verified, and validated as being clinically suitable.

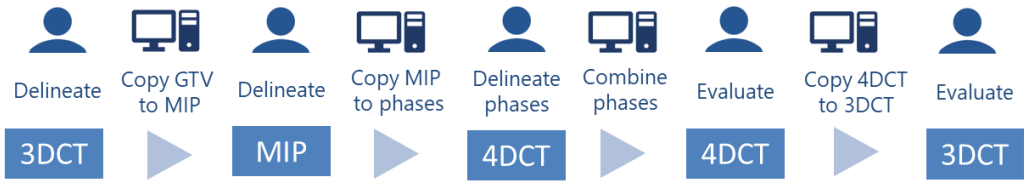


Fig 1. Developed delineation pathway, manual and automated steps shown.

The average time saved using the script was found to be approximately 6 minutes.

Discussion

Software development took longer than anticipated due to unexpected TPS behaviours, which required altering the pathway or recreating existing TPS functions to behave in the desired manner. The script went through several cycles of development to accommodate these adjusting behaviour requirements.

The developed script noticeably reduced the number of steps a user was required to perform, and pop-up notifications at each step informed the user exactly what to perform next.

Conclusion

The potential for improving radiotherapy treatment pathways via automation has been presented in the context of 4D delineation for lung SABR radiotherapy. In this scenario, a reduction in necessary staff training, error likelihood, and the time required has been shown.

Key references.

Reducing Region of Interest Export Errors Through Automation

M Tyyger [1], I Bond [1]

1. Leeds Cancer Centre, Leeds Teaching Hospitals NHS Trust, Leeds, UK

Background

Between the complexities of radiotherapy pathways and treatment planning systems (TPS), it is unsurprising that staff can frequently make minor mistakes when exporting treatment data for later use. Locally, it was identified that approximately 25% of reported Radiotherapy Physics errors over six months were related to incorrectly exported regions of interest (ROIs) from the TPS. Whilst it is rare these mistakes would lead to adverse patient outcomes, they can cause treatment delays and require staff to spend time fixing subsequent issues. Automation can mitigate these minor, but frequently problematic, TPS tasks.

Here, we discuss “SetExportSettings” a simple script designed to automatically set ROI export settings in a TPS to ensure only the correct structures are exported.

Methods

The requirements were a Python script, usable within a TPS Python environment which correctly sets a flag inside the TPS whether to export an ROI based on, its type (target, organ at risk, or other), and their name. The designed logic was meant to apply to all current and future treatment pathways. It was preferable to avoid using pathway-specific configuration files for the anticipated 40+ pathways due to the overhead of producing and maintaining those files.

Results

A script was developed, verified, and validated by Clinical Scientific Computing and Radiotherapy Physics staff members.

It used a single external configuration file to allow Radiotherapy Physics to change some behaviours of the script without requiring Scientific Computing input.

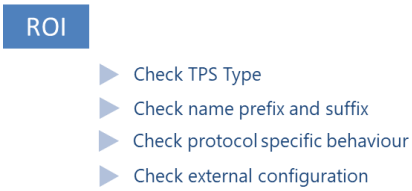


Figure 1. Performed checks for each ROI to set the export setting

An audit is on-going to assess the impact in reported errors since the clinical deployment of the script.

Discussion

During development it became clear that managing all treatment pathways without requiring the script to be altered was potentially an unachievable goal. Certain pathways were found to have conflicting behaviours for the same ROIs. Therefore, where necessary pathway-specific logic was added.

Clinical deployment of the script did not raise any unexpected issues, and initially appears to have reduced the number of errors seen. However, an on-going audit is being performed to ensure systematic errors have not been introduced for any individual treatment pathway.

Conclusion

This project has shown the potential to reduce common radiotherapy errors occurring from incorrect settings inside a TPS using simple automation.

Key references.

Title of Study: Evaluation and clinical implementation of deep learning auto-segmentation across all clinical sites

Josh Mason, Sarah Robinson, Ingrid Johnson, Jack Doherty, Jack Miskell, Meagan de la Bastide, Ruth McLauchlan
Imperial College Healthcare NHS Trust

Abstract no more than 1 page in Arial 11 point, presenting speaker underlined

Background.
Deep learning segmentation (DLS) can automate region of interest (ROI) delineation in radiotherapy treatment planning, offering the potential for significant time saving, improved efficiency and improved consistency/adherence to guidelines.

At Imperial College Healthcare NHS Trust DLS has been implemented for all planned radiotherapy treatments. This study describes the work done to evaluate DLS solutions from two commercial vendors and ensure safe implementation into the clinical pathway.

Methods.
5-10 patients per clinical site (45 patients in total) were evaluated retrospectively by comparing the manually contoured ROIs used in their clinical treatment to the respective DLS generated ROIs. Qualitative evaluation by experienced planners and clinical oncologists involved rating each DLS ROI on a 1-4 scale. Quantitative evaluation compared manual and DLS ROIs geometrically using DICE similarity coefficient (DSC) and dosimetrically by comparing dose volume histogram (DVH) statistics for the clinical plan calculated for manual and DLS ROIs. Automated scripts were used to assist evaluation and to simplify the process of adjusting DLS generated ROIs. A workflow for clinical implementation was developed and each clinical site is being audited a few months after implementation to ensure DLS ROIs are being reviewed and adjusted appropriately.

Results.
From qualitative evaluation, all ROIs were considered suitable for use with manual review and adjustment. Specific issues for users to look out for and differences from local contouring practice were identified. Quantitative DSC results varied especially due to differences in the superior-inferior extent that structures were contoured to. Dosimetric evaluation showed the differences between manual and DLS ROIs mostly had clinically insignificant impact on DVH values, though specific issues were identified for certain OARs particularly brainstem and optic pathway ROIs. Clinical implementation has been effective with the one issue identified being staff remembering to delete unwanted ROIs that otherwise have the potential to cause confusion later in the patient pathway. An audit has been completed for breast and thorax ROIs showing safe implementation although it also identified that use of DLS ROIs resulted in clinically insignificant changes to contouring practice due to the user being guided by the DLS ROI to some extent.

Discussion.
Evaluating and implementing DLS is a significant amount of work however both qualitative and quantitative evaluation are useful to identify potential issues with specific ROIs before proceeding to clinical implementation. Post-implementation audits are useful for better understanding the impact of clinical implementation.

Conclusion.
Deep learning auto-segmentation has been successfully implemented across all clinical sites. Further work will assess the impact of DLS ROIs in terms of time saving and impact on staff workload through regular user surveys.

Key references.
Automation, Deep learning segmentation

Failure rates and Quality Assurance of commercial AI auto-segmentation systems for head and neck cancer

Simon Temple, Carl Rowbottom
The Clatterbridge Cancer Centre NHS Foundation Trust

Background.
AI-based commercial software can be used to automatically delineate organs at risk (OAR) on CT scans, with the potential for significant efficiency savings in the radiotherapy treatment planning pathway, and simultaneous reduction of inter- and intra-observer variability. It is important that a suitable Quality Assurance (QA) program is implemented for such systems[1], which requires a good understanding of expected failure rates and the reason for these failures.

Methods.
A commercial AI auto-segmentation system was used to generate four commonly used OARs on 500 anonymised H&N patient datasets. Auto-segmented contours were compared to existing clinical contours, outlined by an expert human, and a failure rate was set at three standard deviations below the expected mean Dice Similarity Coefficient (DSC), based on a previous study[2]. Failures were classified into one of five groups (setup position, anatomical, image artefacts, suboptimal clinical contour and unknown). Failures relating to suboptimal contouring of the original clinical structure were removed, to produce a 'true failure' rate for each OAR.

Final true failure rates were used to inform recommendations for system QA.

Results.
The study resulted in consistently high quality AI auto-segmentation with a commercial system for H&N cancer patients, with few failures from a large sample size. A summary of results are given below.

Table 1. AI auto-segmentation failure rates for 500 patients

	Brainstem	**Mandible**	**Lt Parotid**	**Rt Parotid**
Total Failures	4	20	13	7
Failure Reason:				
Setup position	2	0	0	1
Anatomical	0	8	5	2
Dental artefacts	0	3	0	1
Clinical structure suboptimal	2	9	6	3
Unknown	0	0	2	0
True failures (Total – clnical error)	**2**	**11**	**7**	**4**
True failure rate	**0.4%**	**2.2%**	**1.4%**	**0.8%**

Discussion.
Where true failures of the auto-segmentation system were identified, there was often a non-standard element associated with the planning CT dataset, for example unusual setup position or unusual anatomy. It can be hypothesised that these non-standard elements were the cause of the failure, and further suggested that the patient datasets used to train the DL model did not contain sufficient heterogeneity of patient data.

Conclusion.
The true failure rate for AI auto-segmentation systems in the H&N region for the OARs investigated is extremely low, in the range 0.5-2%. Due to this very low failure rate, human inspection alone is unlikely to be effective or efficient in identifying failures. It is therefore advised that QA of auto-segmented OARs should utilise automated methods.

Keywords: AI auto-contouring, Quality assurance.

Key references.
1. Vandewinckele L., Claessens M., Dinkla A., Brouwer C., Crijns W., Verellen D., et al. Overview of artificial intelligence-based applications in radiotherapy: Recommendations for implementation and quality assurance. Radiother Oncol 2020;153:55–66. Doi: 10.1016/j.radonc.2020.09.008.
2. Temple, S. (2022). *An evaluation of AI auto-segmentation for Head & Neck cancer*. DClinSci. The University of Manchester.

Title of Study

Automated **C**linical **T**reatment Planning: from manual to auto-planning in Clinical Practise to reduce the patient pathway.

Authors: Anna Vella, Aoife Gallagher, Laura Stubbs, Harkirat Singh, Maxwell Robinson, Sriram Padmanaban
Oxford University Hospitals NHS Foundation Trust, Oxford, United Kingdom

Background: Breast and Prostate are the most common treatment sites in radiotherapy, representing approximately two thirds of all patients receiving radiotherapy. Planning automation for these sites is fundamental to reducing the patient pathway, increasing conformity of treatment quality, and reducing treatment planning times [2][3].

Methods: Automated **C**linical **T**reatment Planning (ACT) was conceived as a rapid and efficient tool to streamline breast and prostate radiotherapy treatment planning at local institution. ACT was developed using an in-house Eclipse [1][4] Scripting Application Programming Interface (ESAPI) for inverse planning with IMRT and VMAT technique to automate dose optimization and efficiently produce high-quality treatment plans. Plans were generated starting from a simple protocol which consisted of the constraints for PTV targets and organs at risk (OAR) such as lungs and heart for breast. The performance of the automatic approaches was evaluated in terms of treatment planning time, target coverage, target dose heterogeneity, and OAR sparing.

Results: ACT-Breast was retrospective tested and assessed on 20 breast patients before starting its clinical use. Following a local audit of subsequent clinical use, the initial release was improved to support planning with newly installed TrueBeam Linacs and latest Varian calculation algorithm. ACT-Breast has drastically reduced total treatment planning times to approximately 10 minutes, with the actual ACT plan creation time ~ 1 mins, in comparison to approximately 45min for manual planning. ACT-Prostate is currently a prototype and will be tested and assessed similarly to ACT-Breast. The prototype supports automatic optimisation with RapidPlan models and DVH Estimation and creates an acceptable initial dose plan.

Discussion: ACT automatically generates clinically suitable radiotherapy plans in a time efficient manner. In challenging cases where ACT may produce clinically sub optimal plans, ACT offers a base for further improving plans in a second optimisation run i.e. combining automated and manual planning where appropriate to maximise clinical care for patients. ACT offers the potential to significantly reduce the patients' care path.

Conclusion: Clinical use of ACT-Breast creates the basis for further auto-planning development with the aim to achieve general timesaving, consistent and conformal dosimetry in planning. ACT-Prostate prototype will be further developed by extending auto-planning to other conformal VMAT sites such as simple pelvis (rectum, gynae, bladder) or more complex planning supported by RapidPlan Models such as Head&Neck.

Key Words: Auto-Planning, Breast, Prostate, VMAT, IMRT, Radiotherapy, Treatment Planning, Eclipse ESAPI Scripting, RapidPlan.

Key references:

1. Varian, Palo Alto, CA
2. K. Spencer et al., The Lancet Oncology 22, 2021.
3. B. V. Offersen et al., Radiotherapy and Oncology 114, 2015.
4. Joakim Pyry and Wayne Keranen, Varian APIs, 2018

Figure 1: ACT-Breast Graphic User Interface.

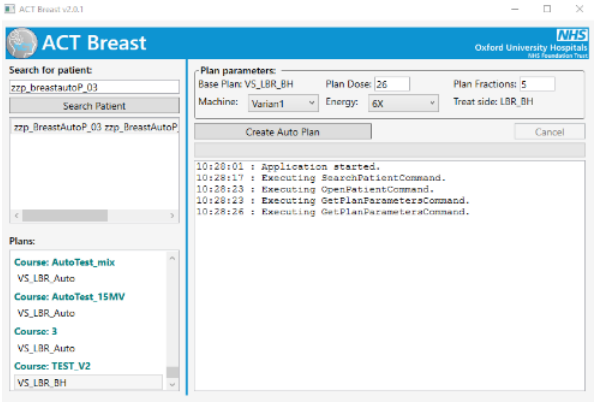


Figure 2: ACT-Breast Dosimetry Results – Clinical Goals. PTV_DVH coverage at D98%, Heart, Body, Heart and Lungs constraints for the same test patient are comparable for all the plans manual (1st column), first release of ACT-Breast (2nd column), second and current release of ACT-Breast with iX Clinacs AAA Calculation model, and with TrueBeam/Acuros (3rd and 4th colums) (all results within ~2%).

Overview

Clinical goals: All Plans — Evaluate Goals for All Plans

Plan			■ 1 / LBrea...	▲ 2 / LtBre...	● 3Test_iX /...	☼ 3Test_TB...
Total Dose			26.000 Gy	26.000 Gy	26.000 Gy	26.000 Gy
Clinical Goal Summary			0 1 9	0 1 9	0 1 9	0 1 9
PTV_DVH	P2	D 98.0 % > 95.0 %	96.20 %	95.31 %	95.21 %	95.04 %
	P2	V 105.0 % < 5.0 %	1.19 %	0.00 %	0.00 %	0.02 %
BODY	P3	D 0.0 % < 107.0 %	105.77 %	103.25 %	104.63 %	105.44 %
Heart	P1	V 1.50 Gy < 30.0 %	14.32 %	13.81 %	14.00 %	11.37 %
	P1	V 7.00 Gy < 5.0 %	0.03 %	0.10 %	0.07 %	0.07 %
	R	Dmean > 0.00 Gy	0.78 Gy	0.78 Gy	0.77 Gy	0.76 Gy
Left Lung	P1	V 8.00 Gy < 15.0 %	15.55 %	15.63 %	15.19 %	16.11 %
	R	Dmean > 0.00 Gy	4.18 Gy	4.10 Gy	4.02 Gy	3.94 Gy
Right Lung	P1	V 8.00 Gy < 15.0 %	0.00 %	0.00 %	0.00 %	0.00 %
	R	Dmean > 0.00 Gy	0.06 Gy	0.05 Gy	0.05 Gy	0.12 Gy

Title of Study: Implementing an automated treatment plan checking script

Submitters details: Ben Harris, Radiotherapy Physicist, Weston Park Cancer Centre.
Jonathan Hughes, Senior Radiotherapy Physicist, Weston Park Cancer Centre.

Background.

Independent checking of treatment plans by physics staff is time consuming and error prone [1]. It has been shown that by automating checks suitable for computer evaluation, the plan error rate and checking time can be reduced [2,3,4,5]. Based on these findings, we have implemented an automatic checking script to improve the efficiency of our planning and checking. We audited this process to identify further checks that can be automated, and to track our error rate over time.

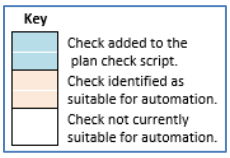
Methods.

An Eclipse script was developed, following best practices in software development. A 6-week audit of plan checking was carried out before the implementation of the script. A second audit was carried out a year later to identify further checks that could be automated. A software QA programme (including an automated self-test routine) was implemented to provide continuing confidence in the integrity of the script, and to maintain plan checker competency.

Results.

Table 1: Results from the 1st and 2nd audit.

	1st Audit			2nd Audit		
Plan Check	**Number of Errors**	**Average time lost / mins**	**Total time lost / mins**	**Number of Errors**	**Average time lost / mins**	**Total time lost / mins**
Plan quality and DVH stats	28	13.9	388.0	26	6.7	174.0
Correct dose rate and field times	21	6.5	136.7	0	0.0	0.0
Secondary dose calculation	21	6.0	126.0	15	7.6	114.0
Setting up distance & shifts	31	4.2	130.0	53	5.0	266.0
Appropriate linac booked	11	6.1	67.3	10	4.0	40.0
Reference point checks	10	6.8	68.0	8	4.9	39.0
Matching structures correct	8	11.8	94.7	11	6.6	73.0
Paperwork checks	38	8.8	334.3	35	5.2	183.0
Contours	18	24.0	432.3	28	36.7	1028.0
Field IDs	10	5.1	51.3	14	2.4	33.0
MLC jaws backed up with collimators	5	22.0	110.0	0	0.0	0.0
Plan normalisation method	5	5.8	29.0	0	0.0	0.0
Prescription checks	4	16.3	65.0	14	5.6	78
Image DICOM origin checks	4	11.3	45.0	0	0.0	0.0



Discussion.

The 1st audit demonstrated that there was significant time lost on checks well suited for automation. The script now catches these errors before the checking stage and so improves the efficiency of the process, saving an average of 1.1 minutes per plan. The 2nd audit revealed further errors that will be added to the next version of the script. Our software QA programme gives us confidence in the integrity of the script and has not identified any serious software errors.

Conclusion.

The plan check script has eliminated time lost in checking and resolving errors for several checks. This is an ongoing project which, coupled with regular plan-checking audit, aims to continuously improve our efficiency and reduce our error rate to improve patient safety. Automated plan checks offer significant prospects for resource saving and risk reduction, provided they are implemented according to best practices in software development and maintained and monitored with a rigorous QA programme.

Key references.

[1] Clouser E L, Chen Q, Rong Y. Computer automation for physics chart check should be adopted in clinic to replace manual chart checking for radiotherapy. *J App Clin Med Phys.* 2021; 22(2): 4-8.
[2] Liu S, et al. Optimizing efficiency and safety in external beam radiotherapy using automated plan check (APC) tool and six sigma methodology. *Rad onc Phys.* 2019; 20(8): 56-64.
[3] Dewhurst J M, et al. AutoLock_ a semiautomated system for radiotherapy treatment plan quality control. *J App Clin Med Phys*. 2015; 16(3).
[4] Covington E L, Popple R A, Cardan R A. Technical Note: Use of automation to eliminate shift errors. *J App Clin Med Phys.* 2020; 21(3): 192-195.
[5] Covington E L, et al. Improving treatment plan evaluation with automation. *J App Clin Med Phys.* 2016; 17(6): 16-31.

Automated Prostate Planning with ESAPI Scripting and RapidPlan

Gavin Orchin – Beatson West of Scotland Cancer Centre

Background

VMAT radiotherapy plans can be time consuming to create, regularly requiring several hours per treatment [1]. At the Beatson, approximately 1000 VMAT prostate treatments are planned each year and as such they take up a large portion of the departmental planning time. Since 2018, the Beatson has used a partially automated knowledge-based model (RapidPlan) to generate PTV and OAR dose objectives for prostate plans. However, it has been shown that scripting can further reduce the overall planning time while maintaining plan quality and reducing the rate of technical errors [2-5]. Therefore, we now aim to use ESAPI scripting to build upon pre-existing RapidPlan models and streamline the planning process further.

Methods

A plugin script has been developed that works from a CT scan with contoured GTVs and OARs and produces an external beam prostate plan, optimised using the approved RapidPlan model. The main tasks completed by the script are the following:

- Identify existing structures in the structure set
- Margin three PTVs from the prostate GTVs according to the CHHiP protocol
- Contour the gold fiducial markers within the prostate and assign them a density
- Add a treatment couch model
- Create a treatment plan in the correct course
- Select a suitable isocentre position
- Insert treatment fields and setup fields in a standard geometry
- Create a reference point at the centre of the high risk PTV
- Fit treatment field jaws to the PTVs
- Create DRRs
- Add dose estimates and optimisation objectives from the approved RapidPlan model
- Optimise the plan

Results

The script is currently being evaluated for department wide use and will soon be implemented clinically. The automatically performed contouring (PTV margining and high density segmentation) has been found to be highly consistent and near indistinguishable from current methods. Optimisation using a RapidPlan model allows the script to produce a clinically acceptable external beam plan in just a few minutes and the safety checks that the script performs are able to identify contouring and prescription errors at an early stage and should therefore reduce the probability of treatment delays.

Conclusion

The automated prostate planning script that has been developed is expected to create large time savings for the planning department and reduce the rate of repeat planning by preventing errors such as: violations of naming conventions, incorrect structure margining and incorrect structure assignments within RapidPlan.

Key references

1. Moore, K. L. (2019). Automated radiotherapy treatment planning. *Semin Radiat Oncol* 29, 209–18.
2. Gleeson, I., Bolger, N., Chun, H., et al. (2023). Implementation of automated personalised breast radiotherapy... *The British Journal of Radiology*, 95, 20220707.
3. Teruel, J. R., Malin, M., Liu, E. K., et al. (2020). Full automation of spinal stereotactic radiosurgery... *Journal of Applied Clinical Medical Physics*, 21(10), 122-131.
4. Yang, D., & Moore, K. L. (2012). Automated radiotherapy treatment plan integrity verification. *Medical physics*, 39(3), 1542-1551.
5. Yedekci, Y., Gültekin, M., Sari, S. Y., & Yildiz, F. (2023). Improving normal tissue sparing using scripting… *Radiation and environmental biophysics*, 1-8.

Automating the recalculation of clinical SABR treatment plans in an independent TPS to provide 3D dose evaluation at plan check

Aims and/or Background: Stereotactic ablative radiotherapy (SABR) treatments require accurate methods of independently verifying the treatment planning system (TPS) dose calculation. Often, simple dose check software does not adequately account for tissue inhomogeneities, resulting in inaccurate or unreliable verification. As a result, departments may resort to measurement-based patient-specific quality assurance (PSQA) of every patient to verify the TPS dose calculation. With an increasing number of patients receiving SABR treatments, this can place increased time and machine requirements on radiotherapy departments.

The aim of this work is to automate the recalculation of clinical SABR treatment plans on a second TPS in order to save time checking plans, reduce the requirements of PSQA measurements on the treatment machine, as well as providing a tool for evaluating a 3D dose distribution at physics check.

Methods: A 10FFF beam model was commissioned and verified in Raystation for checking Eclipse dose calculations. The model was verified against previous PSQA measurements and compared to Eclipse for 81 clinical SBRT treatment plans. A script was developed for Raystation that automatically recalculates the dose distribution for plans exported from Eclipse, and subsequently exports the DICOM Dose and Plan files for direct import into the Aria Database using the Varian DICOM Daemon. Once a clinically acceptable plan has been produced, the planner exports the plan using an export filter configured in Aria and the Raystation script automatically generates the check plan overnight. The recalculated check plan and its 3D dose distribution is then available within Aria for the plan checker the next day for comparison with the Eclipse clinical plan, as well as commercial independent dose check software.

Results: The mean ± standard deviation calculation error for Raystation point-dose PSQA plans was -0.9%±1.2% whilst for Eclipse it was 2.0%±2.3%. Similarly, the mean ± standard deviation PTV D95% (Gy) was -2.3Gy±1.0Gy for plans calculated using the Raystation model compared to Eclipse. Using the automation script reduces the time required to check a SBRT plan, and removes the repetitive tasks of importing, calculating, and exporting on Raystation. The check plan is available in Eclipse the following day, allowing a direct 3D dose comparison with Eclipse, whereas commercial independent dose check software often verifies a single point.

Discussion around results: The smaller PSQA calculation error using the checking (Raystation) beam model provides confidence in its use as an independent verification tool. The differences in the PTV D95% metric between Eclipse and Raystation can be used as a tolerance to help decide whether further PSQA is required. The automated recalculation of SABR plans using a second model provides a valuable resource for checking SABR plans, provides more information for the checker, including the ability to evaluate conformance to target and OAR constraints on the check plan, and reduces the time required to check. It is not dependent on machine time and thus reduces the burden of the physics team for PSQC.

Conclusion: 10FFF beam model was developed on a second TPS to act as independent dose check of SABR plans. Using a script to automate this verification check is an efficient way to verify the dose distribution and relieves some of the burden on the physics QC for machine time for PSQC.

Key Words:

- SABR, Eclipse, Raystation, Plan verification, Plan checking, independent dose check

An overview of treatment planning automation used for proton beam therapy at The Christie

Samuel Ingram[1,2], Matthew Clarke[1], Matthew Lowe[1,2], and The Christie PBT Physics Team[1].
[1]Christie Medical Physics and Engineering, The Christie NHS Foundation Trust, Manchester, UK.
[2]The University of Manchester, Manchester, UK.

Background: Proton beam therapy (PBT) is a specialised form of radiotherapy can offer that dosimetric benefits to a selection of patient sites. As PBT is a specialised form of radiotherapy and less widespread there are several features that the commercial treatment planning systems are not well equipped to provide yet. In this work, we will discuss how we've used a range of scripting solutions to account for these missing features along with other solutions to improve areas of technical contouring and plan checking.

Methods: Scripting work has been carried out using Varian's Eclipse Scripting Application Programming Interface (ESAPI) for v16.1 of the Eclipse Treatment Planning System. These scripts are written in C# and use a range of user interfaces, config files and higher-level input files to ensure widespread adoption across the whole Physics team. Our approach to scripting, when possible, is to design solution frameworks that are not dependent on programmers to expand allowing us to achieve our clinical aims through the efforts of the wider team. Thus, allowing the programmer time to be focused on the continuation of the development of new solutions and minimisation of scripting feature updates. In this overview we will discuss the following automation scripts: (1) Plan Assessment Forms – automated dosimetric (including worst-case values in robustness scenarios) extraction for a range of clinically agreed metrics; (2) Worst Case Scenario Plans – a voxel-wise 3D dose map of the maximum and minimum dose values across all robustness scenarios; (3) Contour Cook Book – a parser which allows simple user made scripts to be run to create technical volumes automatically; (4) Auto CSI – a tool to allow for the automation of technical structures, isocentre positioning and beams for Cranio-Spinal Irradiation (CSI) patients; (5) Plan Check Script – a tool for plan checkers to automatically collate the results of a range of standard plan checks.

Results: Each of the scripts mentioned have a clinical impact in improving our functionality and efficiency during treatment planning. Figure 1 outlines some of the key aspects of these scripts to how we have tried to maximise these impacts.

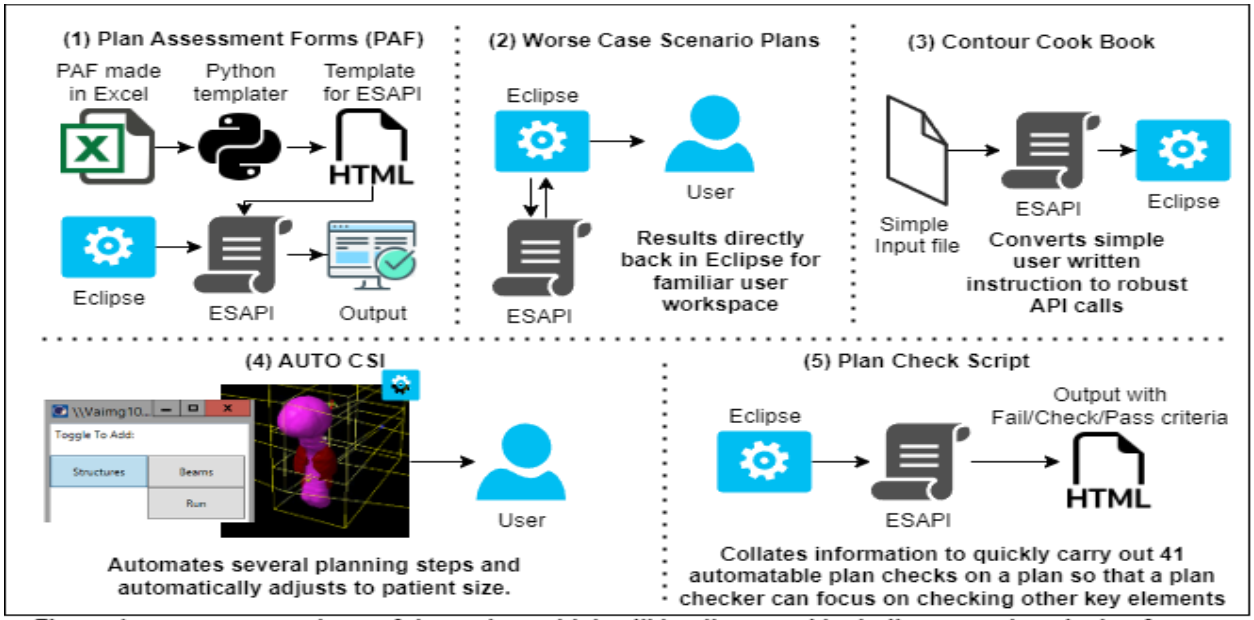


Figure 1 - process overviews of the scripts which will be discussed including some key design features used to improve accessibility and utility of each.

Discussion: We are continuing to develop scripts and utilise their potential clinically. We have worked focused on ensuring the sustainability of this work going forward as clinical pressures are likely to increase. Furthermore, to better understand the impact of these scripts we are aiming to introduce a range of collected metrics for each script which will help us to highlight their importance to both ourselves and the wider staff groups.

Conclusion: Scripting provides an invaluable tool for PBT treatment planning and has allowed us to compensate for missing features found in commercial treatment planning systems.

Comprehensive dosimetric evaluation of a CT scanner based deep learning auto-contouring solution for prostate radiotherapy

Berenato S.[1], Williams M.[1], Woodley O.[1], Möhler C.[2], Evans E.1, Millin A.E.[1], Wheeler P.A.[1]

[1]Velindre Cancer Centre, Cardiff, Wales, United Kingdom.
[2]Siemens Healthineers, Forchheim, Germany

Background: For extreme hypo-fractionated prostate radiotherapy, this study geometrically and dosimetrically evaluated DirectORGANS: a novel commercial AI solution that is natively integrated into a CT scanner and utilises dedicated reconstructions optimised and standardised for auto-contouring.

Methods: CT scans of 20 prostate patients were sequentially selected to evaluate AI contouring for rectum, bladder and proximal femurs. 5 plan generation 'pipelines' were considered. 3 used AI contours with differing levels of manual editing: nominally none (AI_{Std}), minor editing in specific regions e.g. target/OAR boundaries ($AIMin_{Ed}$), and fully corrected (AI_{FullEd}). The remaining 2 were manual delineations from different observers (MD_{Ob1},MD_{Ob2}). MD_{ob1} was defined as the reference contour set in all analysis. Contouring time was recorded and plans generated for each pipeline using a validated automated planning solution. The geometric and dosimetric agreement of contour sets AI_{Std}, $AIMin_{Ed}$, $AIFull_{Ed}$ and MD_{Ob2} were evaluated against the reference set MD_{Ob1}. The non-inferiority of the AI pipelines was assessed with the testing hypothesis that 'absolute deviations in geometry and dose metrics for AI contouring (vs MD_{Ob1}) were no greater than that from a second observer (MD_{Ob2})'. For dosimetric comparison the error in Reported Dose (RD) and Patient Dose (PD) was evaluated. RD was defined as DVH parameters that would be reported in patient records for a given pipeline.The dose distribution generated by each pipeline plan was evaluated on both the reference (RD_{Ref}) and pipeline ($RD_{Pipeline}$) contour sets, with the difference calculated to assess the impact of contour discrepancies on RD. PD, defined as the best estimate of the actual dose the patient would receive, was extracted from the pipeline plan's DVH using the reference contour set ($PD_{Pipeline}$). By comparing $PD_{Pipeline}$ with plans generated by and evaluated using MD_{Ob1} (PD_{Ref}), a contour set's influence on the optimisation process and hence final dose distribution, was assessed.

Results: Compared to MD_{Ob1}, overall delineation time for AI_{Std}, AI_{MinEd} and AI_{FullEd} was reduced by 24.9min (96%), 21.4min (79%) and 12.2min (45%) respectively. AI_{Std} contours exhibited good geometric alignment to MD_{Ob1} with median DSC results of 0.89, 0.95, 0.96 and 0.95 for rectum, bladder, femur_R and femur_L respectively. Minor editing led to marginal improvements but both AI_{Std} and AI_{MinEd} DSC results were statistically inferior to MD_{Ob2}. All pipelines exhibited generally good dosimetric agreement with MD_{Ob1}. For RD, median deviations were within ±1.8cm^3, ±1.7% and ±0.6Gy for absolute volume, relative volume and mean dose metrics respectively (Figure 1). For PD, agreement was improved with respective values within ±0.4cm^3, ±0.5% and 0.2Gy. Statistically AI_{MinEd} and AI_{FullEd} were dosimetrically non-inferior to MD_{Ob2}.

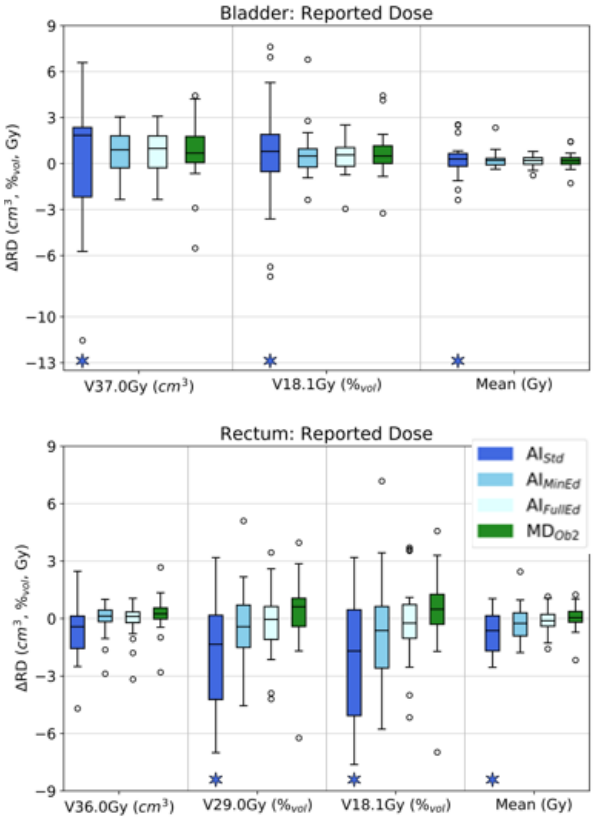


Figure 1: Results of the dosimetric assessment (RD) stars indicate statistical significant in terms of inferiority of the AI pipeline vs MD_{Ob2} ($p<0.05$)

Conclusion: Following minor editing (AI_{MinEd}), AI contours were dosimetrically non-inferior to manual delineations and reduced delineation time by 79%.

Assessing plan quality in the 'PLATO anal cancer trial 5' pilot phase with automated planning

Barrel M.J.[1], Abbott N.[1], Adams R.[1], Hawkins M.[2], Sebag-Montefiore D.[3], Millin A.[1], Wheeler P.A.[1]
1. Velindre Cancer Centre, Cardiff
2. University College of London, London
3. Leeds Cancer Centre, St James' University Hospital, Leeds

Background: Treatment efficacy relies on plan quality. Within trials, plan quality may vary due to training and equipment differences, which may influence treatment outcome or trial results. This study uses automated planning to assess plan quality and variation within the PersonaLlising rAdioTherapy dOse (PLATO) Anal Cancer Trial 5 (ACT5).

Methods: A protocol based automatic iterative optimisation (PBAIO) planning solution [1], implemented in RayStation, was calibrated for anal cancer using 5 pre-trial benchmark patient plans and 10 non-trial patients. Plans were generated for the pilot phase of PLATO ACT5; a dataset of 51 patients from 11 centres. Patients with prosthetic hips, replans, or unavailable suitable planning data were excluded (n=9). All trial plans were approved by the PLATO national trials QA team. The trial and automated plans were quantitatively compared using the ACT5 planning protocol parameters, small bowel V15Gy in cm^3, and planning target volume (PTV) conformity index (CI) and homogeneity index (HI). Statistical analysis was completed using a Wilcoxon signed rank test.

Results: At a population level, automation generally yielded higher quality plans with less variation when compared to trial plans. Automation reduced mandatory and optimal objective failures from 4 to 3 and 137 to 80 respectively.

34/46 metrics showed statistically significant ($p<0.05$) differences between automated and trial plans. Automation significantly reduced OAR dose (Table 1). Genitalia D50% and D35% reduced by >5.5Gy, femoral heads (FHs) by >2.5Gy and bladder D50% by 1.8Gy. Small bowel D200cc and D150cc reduced by 5.0Gy and V15Gy by $41cm^3$. These reductions did not adversely impact PTV D98%, D2%, HI or CI, which were within 0.6Gy, 0.6Gy, 0.018, and 0.017 respectively.

Structure	Metric	Objective		Trial		Automated	
		Man	Opt	Mean	StDev	Mean	StDev
Small Bowel	*D200cc (Gy)*	<35	<30	17.7	9.5	12.7	7.9
	D150cc (Gy)	<40	<35	20.3	10.0	15.2	9.2
	D20cc (Gy)	<50	<45	35.0	10.2	31.8	12.2
	D5cc (Gy)	<55	<50	40.4	7.9	38.6	10.2
	V15Gy (cc)	N/A	N/A	161.9	118.1	121.3	105.2
Left FH	*D50% (Gy)*	<45	<30	26.3	2.6	23.7	3.1
	D35% (Gy)	<50	<40	28.7	2.5	26.0	2.9
	D5% (Gy)	<55	<50	35.5	2.4	32.8	2.3
Right FH	*D50% (Gy)*	<45	<30	26.0	3.3	23.2	2.9
	D35% (Gy)	<50	<40	28.4	3.4	25.7	2.8
	D5% (Gy)	<55	<50	34.7	3.0	32.8	2.5
Genitalia	*D50% (Gy)*	<35	<20	23.2	5.3	17.3	3.3
	D35% (Gy)	<40	<30	27.1	5.5	21.4	5.5
	D5% (Gy)	<55	<40	42.6	9.0	39.8	11.3
Bladder	*D50% (Gy)*	<45	<35	32.6	5.1	30.7	5.4
	D35% (Gy)	<50	<40	37.1	4.7	36.2	5.2
	D5% (Gy)	<58	<50	48.2	5.3	48.4	5.5

Table1 - Trial and auto plan DVH data. *Italic* and underline indicate statistically significant differences. Man=Mandatory, Opt=Optimal PLATO ACT5 objectives.

At a per patient level, substantial variation in the difference between trial and automated plan metrics indicated noteworthy plan quality variability. For the genitalia and FHs, interquartile range (IQR) of the difference (trial-auto) was largest for D35%; 5.8Gy and 5.2Gy respectively. For the bladder, D50% IQR was 4.5Gy. The small bowel D200cc and V15Gy IQRs were 7.7Gy and $46cm^3$ respectively. Meaningful variations in PTV D98%, D2%, CI and HI were also observed with IQRs of up to 2.4Gy, 2.4Gy, 0.018, and 0.060 respectively.

Conclusion: Automated planning highlighted significant variations in plan quality within the pilot phase of PLATO ACT5. Evaluating plan quality in this manner may encourage improvements in training, QA and future trial approaches. This may reduce variation and improve overall plan quality.

Key references:

[1] P. Wheeler et.al, "Utilisation of Pareto navigation techniques to calibrate a fully automated radiotherapy treatment planning solution", *Phys Img Radiat Oncol,* vol. 16, no. 10, pp. 41-48, 2019

Development and Clinical Implementation of an Automated Radiotherapy Prostate Planning Script using the RayStation Scripting Interface

Authors: Richard Powis and Gareth Webster

Worcestershire Oncology Centre, Worcester Royal Hospital

Background:

VMAT prostate radiotherapy plan optimisation is dependent on the patient anatomy, the skill and experience of the planner and the time available. Scripts in Raystation TPS can be used to efficiently audit historic plan quality and have been employed locally as an effective tool to guide the manual VMAT plan optimisation process and reduce organ at risk doses (OAR) [1]. An in-house Raystation automatic planning script (AutoPlan) has been developed and implemented for prostate radiotherapy with a view to minimise manual input whilst producing high quality clinical plans.

Method:

AutoPlan fully automates the plan production process growing PTV(s) and plan optimisation structures, creating a VMAT arc and fully optimising the plan to produce a high quality dose distribution that meets all clinical goals for standard clinical cases. The script utilises an existing local knowledge-based planning (KBP) model [1] and an iterative plan optimisation process.

AutoPlan was implemented into an experienced team, following training and advice to consider manual intervention if worthwhile. Prostate plan quality was regularly audited using the RayStation scripting interface to monitor the performance of AutoPlan. Over subsequent audits it was noticed that planners were able to achieve modest improvements on the original knowledge base using the plan produced by the AutoPlan as a foundation. The knowledge base was re-baselined and incorporated into a second version of the script (AutoPlanV2) which was subsequently introduced into clinical use.

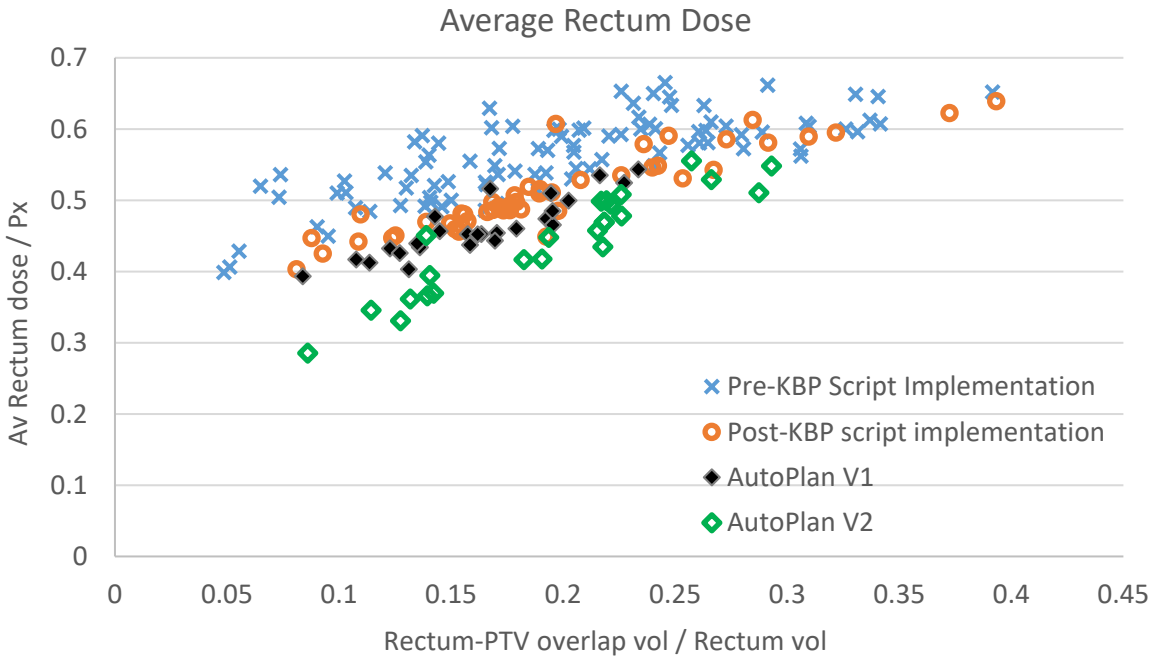
Results: Manual prostate plan optimisation guided by an existing local Raystation KBP script [1] (see hollow circles in figure below) has previously been shown to produce good quality plans with significantly lower average rectum doses compared to manual planning alone (see crosses in figure below). Introduction of AutoPlan was found to produce plans of comparable high quality with modest improvements to rectum average dose and minimal manual input (see solid diamonds in figure below). The introduction of AutoPlan2 was able to further improve cohort average rectum dose with minimum manual input (see hollow diamonds in figure below).

Conclusion:

An automated planning script has been developed and refined using the RayStation scripting interface to produce high quality clinical prostate plans with minimal user input.

Key References:

1] Clinical implementation of a knowledge based planning tool for prostate VMAT, Powis et al. Radiation Oncology (2017) 12:81


Average Rectum Dose
Av Rectum dose / Px
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Rectum-PTV overlap vol / Rectum vol
Pre-KBP Script Implementation
Post-KBP script implementation
AutoPlan V1
AutoPlan V2

Automated Optimisation Structure Generation for Head and Neck Radiotherapy Planning

Henry Carver, Daniel Egleston, Russell Dawson, Simon Temple
The Clatterbridge Cancer Centre NHS Foundation Trust, Liverpool, United Kingdom

Abstract no more than 1 page in Arial 11 point, presenting speaker underlined

Invited talks - an abstract summarising you presentation is welcome including any images or tables.

Proffered papers - please follow the style below:

Background. Background to the study and aim of study including 5-10 key references.

Planning of complex radiotherapy treatments involves the generation of optimisation structures. These are grown from anatomical structures according to simple geometrical rules. The process of creating optimisation structures from planning structures is time consuming and prone to error, especially for complex sites such as radiotherapy to the head and neck.

Methods. Key methods used in the study including diagrams, images as necessary.

A C# script was developed leveraging the Eclipse Scripting API (ESAPI) to generate optimisation structures for inverse-optimised radiotherapy planning. This is achieved by pattern matching in the structure name to determine the type of structure. This matching method is robust for a range of treatment sites and structure names.
The script takes as input a structure set containing populated CTVs and OARs, it will then automatically populate any planning target volumes, hot structures, cold structures, opt structures and planning risk volumes in the structure set.

Efficiency will be measured using self-reported timing of structure creation by treatment planners. This has been done before and after script deployment for a set (N=50) of head and neck plans with a range of plan complexity. This will be supplemented by a retrospective audit of plan rejection rate following structure checking by an independent physicist. Feedback from beta testers has been recorded by questionnaire.

Results. Results of the study including diagrams, images, tables as necessary.

The results of the quality improvement audit will be presented at conference as this audit has not yet completed.

Initial feedback from beta testers has been very positive, citing time saving and efficiency as significant improvements.

Discussion. Discussion of the significance of the results

The script has the potential to improve the efficiency and quality of head and neck radiotherapy planning by automating the tedious and time-consuming task of optimisation structure generation. The script also reduces inter-planner variability and enhances standardisation of planning practices. The structure matching algorithm is flexible and robust for different sites and anatomies, and can be easily adapted for other regions of interest.

Conclusion. Conclusion relating to the aim of the study.
We have developed a C# script that automatically generates optimisation structures for head and neck radiotherapy planning using a novel structure matching algorithm.

The script has been well received by beta testers and has shown promising results in terms of planning time reduction and planner consistency. We aim to present audit results showing the impact of the script on clinical outcomes.

Key references. In alphabetical order, numbered.

Automation, ESAPI, optimisation, planning, radiotherapy, structure generation